UV-Induced Insulator Flashover

Jay B. Javedani
(925) 422-8569
javedani1@llnl.gov

In high-energy pulsed power systems, an insulator's main function is to provide an interface between regions of insulating fluid/gas and vacuum that separate electrodes at different high-voltage potentials. It is known that the vacuum surface of the insulator will flashover when illuminated to a critical dose of ultraviolet (UV) radiation, depending on the insulator material, insulator cone angle, applied voltage, and insulator's residual charge. Surface flashover refers to the cascade of electrons across the insulator's surface leading to the immediate collapse of voltage between the electrodes.

The UV radiation may be generated by ohmic heating of metal surfaces, coronas in high electrical field regions, or plasmas from explosive emission. As the power of the pulsed power system is increased, so is the UV fluence. An accurate knowledge of the UV fluence (energy per unit area) required for flashover is critical for producing the next generation of high-power flow systems.

Figure 1. Photograph of experimental setup.

Project Goals

The objective of this project was to conclude the measurement of UV fluence required for flashover of four candidate insulator materials and cone angles. The data gathered not only validated some of the measurements reported in the 1980s, but also extended the knowledge base to present parameters. These results are useful to electrically stressed, UV-radiated systems in many pulsed power applications.

Relevance to LLNL Mission

For many systems the delivery of pulsed power into a vacuum region is the most critical factor impacting performance and reliability. The applicability of our investigation in UV flashover performance addresses issues related to power flow channels for flux compression generators. As such, the results have a significant impact on LLNL's national security mission.

FY2008 Accomplishments and Results

A test bed comprised of an excimer laser (KrF, 248 nm), vacuum chamber (10^{-6} torr), and dc high-voltage (< 60 kV) power supply was established in FY2007. Fast capacitive probes (D-dot), the specialized diagnostic for this work, were embedded in the anode electrode underneath the insulator to give the time of arrival of flashover. A photograph of the test bed is provided in Fig. 1.

Testing included four types of 1.0-cm-thick insulator materials: 1) high-density polyethylene (HDPE), 2) a crossed linked polystyrene

Figure 2. Photograph of insulators (clear HDPE, milky Rexolite).

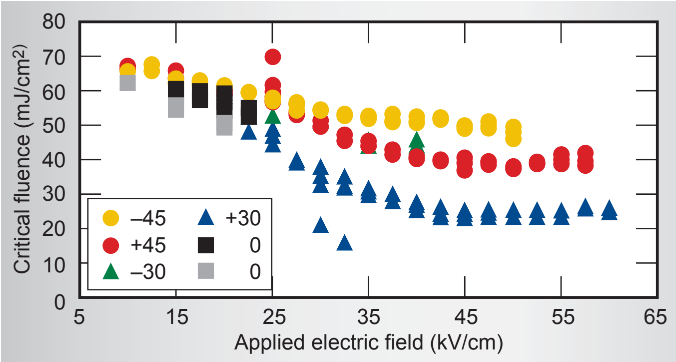

Figure 3. HDPE critical fluence results for different angles.

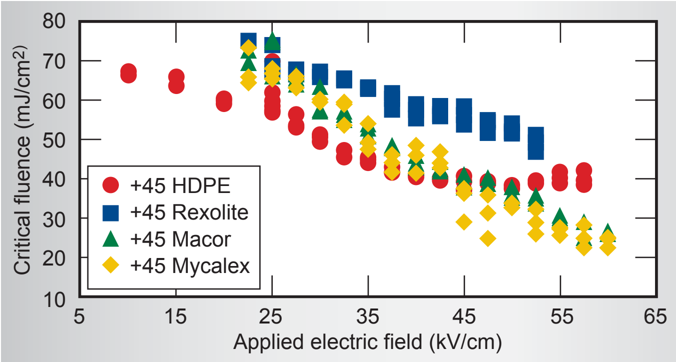

Figure 4. Critical fluence results for different insulator materials, all at +45°.

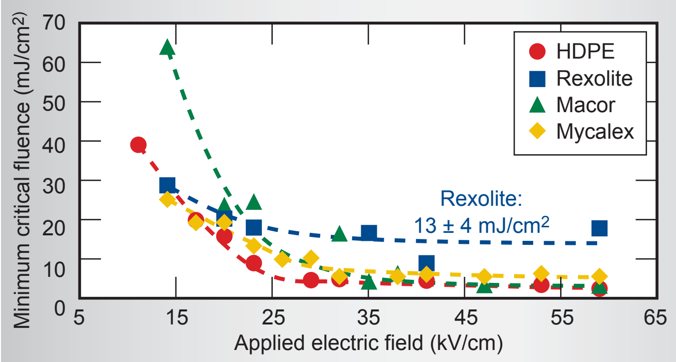

Figure 5. Minimum critical fluence results, all at +45°.

Rexolite® 1400, 3) a silicate-based machinable ceramic Macor,TM and 4) a fluorine-glass-based machinable ceramic Mycalex. The materials were extensively tested with insulator angles of 0, ±30, and ±45 degrees. Figure 2 is a photograph of some of the tested insulators.

The insulator was illuminated to a laser pulse while holding a dc charge (up to 60 kV). The nominal laser energy that impinged on the surface of the insulator was ~70 mJ/cm^2 (FWHM 30 nm, 2 MW/cm^2). More than 2000 data points were recorded, for different configurations of materials and angles. For each data point, the amount of UV dose for breakdown, *i.e.*, critical UV energy density, was measured by integrating the laser output power waveform all the way to the arrival time of flashover indicated by the fast D-dot probes (> 4 GHz bandwidth). Figure 3 shows the angle dependence of UV critical energy density for HDPE. Figure 4 shows the material dependence of UV critical energy density for all the tested materials.

A new effect was observed related to the UV power level on flashover that had not been previously reported. It appears that UV pulses with intensity greater than the minimum UV fluence need more than the established minimum energy/fluence to induce surface flashover. In other words, the energy/fluence required for flashover is also a function of the intensity of the UV pulse. This effect would bias the data toward higher minimum flashover fluence and lead to an incorrect interpretation of the data. Figure 5 shows the minimum critical UV energy needed for flashover. Among the four considered materials, Rexolite® 1400 showed the best UV hold off properties for surface flashover with the newly established minimum critical energy of 13 ±4 mJ.

Related References

1. Enloe, C. L., and R. E. Reinovsky, "Ultra-Violet Induced Insulator Flashover as a Function of Material Properties," *Proc. 4th IEEE Pulsed Power Conf*, **I**, Albuquerque, New Mexico, pp. 679–682, June 1983.
2. Enloe, C. L., and R. M. Gilgenbach, "Microscopic and Macroscopic Material Property Effects on Ultraviolet-Laser-Induced Flashover of Angled Insulators in Vacuum," *IEEE Trans. Plasma Sci.*, **16**, 3, pp. 379–389, June 1988.
3. Javedani, J. B., T. L. Houck, B. T. Kelly, D. A. Lahowe, M. D. Shirk, and D. A. Goerz, "UV Induced Insulator Flashover," *Power Modulator Conference*, Las Vegas, Nevada, April 2008.